# URBAN STORM RUNOFF IN THE ROSEBURG AREA, OREGON, AS RELATED TO URBAN FLOOD CHARACTERISTICS OF THE WILLAMETTE VALLEY

By L.E. Hubbard

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4063

Prepared in cooperation with WATER RESOURCES SURVEY, DOUGLAS COUNTY, OREGON



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	CONVERGION FACTORS	
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Multiply	Ву	To obtain
	LENGTH	
<pre>inches (in) inches (in) feet (ft) miles (mi)</pre>	25.4 0.0254 0.3048 1.609	meters (m)
	AREA	
square miles (mi <sup>2</sup> ) acre	2.590 0.4047	square kilometers (km²) hectare (ha)
	FLOW	
cubic feet per second (ft <sup>3</sup> /s)	0.02832	cubic meters per second (m3/s)
	SLOPE	
foot per mile (ft/mi)	0.189	meter per kilometer (m/km)

# URBAN STORM RUNOFF IN THE ROSEBURG AREA, OREGON, AS RELATED TO URBAN FLOOD CHARACTERISTICS OF THE WILLAMETTE VALLEY

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#### ABSTRACT

Techniques are provided for estimating flood magnitudes for streams in the urbanized parts of the Roseburg, Oregon area for exceedance probabilites (recurrence intervals) of 0.5 (2-year), 0.2 (5-year), 0.1 (10-year), 0.04 (25-year), 0.02 (50-year) and 0.01 (100-year). A network of four continuous-recording streamflow gages, three crest-stage gages, and six precipitation gages was established and operated for a 3-year period (1982 to 1984). A U.S. Geological Survey rainfall-runoff model was calibrated for each site where runoff was measured and was used to produce a series of synthetic flood peaks. These series of flood peaks are based on pan-evaporation records from Canby, Oregon, and long-term unit rainfall records from Portland, Oregon. Flood statistics were computed for these synthetic series following guidelines in Bulletin 17B of the U.S. Water Resources Council.

#### INTRODUCTION

With urban growth and development there is an increasing need for flood information and techniques to evaluate effects of urbanization on flooding in areas where few or no data exist. In response to the need for flood information, the U.S. Geological Survey, in cooperation with local governments, began a small-stream flood-frequency study program. The goal of this program is to provide the types of information needed for drainage design, zoning, and insurance rate adjustments for small watersheds in rural and urban areas. A published report by Sauer and others (1983) describes a nationwide method for estimating flood characteristics for urban areas. Two previous reports by Laenen (1980 and 1983) describe methods for estimating flood characteristics for urban areas in the Willamette River basin of Oregon. The purpose of the study reported here was to assess magnitudes and frequencies of stormwater runoff in the Roseburg area, and in potential growth areas of Douglas County, Oregon.

# Purpose and Scope

This report presents an analysis of data collected in and near Roseburg, Oregon, and compares these results with findings of previous studies in the Willamette Valley. Specifically, regression equations from previous studies were tested for transferability and reliability in estimating urban flood-peak discharges in the Roseburg area.

A rainfall-runoff model was used in this study to define the rainfall-runoff relations for each gaged site. A data-collection network consisting of four continuous recording streamflow gages, three crest-stage gages, and six recording precipitation gages was operated for a 3-year period (1982-84). A digital rainfall-runoff model was

calibrated for each of the streamflow sites. Five-minute rainfall data for approximately five storms per year for 7l years at Portland, Oregon, were available from the National Oceanic and Atmospheric Administration. The calibrated model was used to generate a synthetic series of flood peaks. The generated annual peaks were analyzed with Log-Pearson Type III procedures (Water Resources Council, 1981). Discharges for selected recurrence intervals were then compared with discharge values determined using other estimating techniques.

# Previous Studies

A report by Laenen (1980) presented methods for determining flood frequencies for ungaged urban streams in the Portland-Vancouver area. The resulting regression equations for estimating flood discharges had an average standard error of estimate (SEE) of 30 percent. Laenen's (1980) data-collection network consisted of 24 streamflow gages and 24 rain gages. Basins ranged in size from 0.2 square miles to 26 square miles.

Laenen (1983) extended the geographical coverage of his previous study to the Willamette Valley by collecting and analyzing rainfall-runoff data for an additional 17 basins in the Salem area, Oregon. The study presents a set of three-parameter regression equations (referred to as W-1 for the remainder of this report) that can be used to estimate flood discharges from urban watersheds in the Willamette Valley. The equations have an average SEE of 24 percent.

Sauer and others (1983) used a data base from 269 streamflow records to develop three sets of equations for estimating flood discharges from urban watersheds on a nationwide basis. Data from 22 of the streamflow sites from the Portland-Vancouver study were included in the nationwide analysis by Sauer. The equations include two sets that are based on seven parameters and one set that is based on three parameters. The three-parameter equations (referred to as N-5 for the remainder of this report) utilize the independent variables of drainage area, a basin development factor, and equivalent rural peak discharges. These equations have an average SEE of 43 percent.

Harris and others (1979) developed simplified procedures for estimating the flood-peak statistics for rural watersheds in western Oregon (referred to as WOr for the remainder of this report). By using multiple regression analysis and data for 239 sites, they developed estimating equations for four separate regions of western Oregon. Equations presented for the Rogue-Umpqua region include independent variables of drainage area, storage, and rainfall intensity. The SEE for the equations is 46 percent. The Rogue-Umpqua equations were used to estimate flood discharges for the watersheds in the Roseburg area.

# <u>Acknowledgments</u>

The author thanks the people who have given time, information, and guidance during this study. Particular thanks are given to Kenneth R. Shumway and Francis P. Coggswell of Douglas County for their efforts in maintaining the Roseburg data-collection network.

#### PHYSICAL SETTING

The study area is located at Roseburg, Oregon, about 200 miles south of Portland, Oregon (see fig. 1). Roseburg is situated in the approximate center of the Umpqua River basin in an area referred to as the Central Valley. The Umpqua River basin is bounded by the Willamette River basin on the north and the Rogue River basin to the south. The creeks measured for this study are minor tributaries to the Umpqua River system. Roseburg is the county seat of government for Douglas County. The city's population is 16,644 (1980 census), with an estimated trading area of 60,000 people.

# Climatic Elements

The climate in the Umpqua River basin is characteristic of western Oregon. Temperatures are generally mild, but vary with elevation. The climate has been described as "slightly modified marine" (U.S. Department of Commerce, 1973). The mild seasonal characteristics are well defined with gradual changes noted between seasons. The wet winters yield 81 percent of the annual moisture from October through March; snowfall contributes only 3 percent of this amount. Early May brings a sharp decrease in rainfall and increase in temperature. Mostly sunny dry weather continues into early fall until mid-October.

Annual precipitation totals at Roseburg have ranged from 21.17 inches in 1930 to 46.90 inches in 1891. The Roseburg area receives 47 percent of its annual moisture in winter, 21 percent in spring, 5 percent in summer, and 27 percent in fall. Hourly precipitation records for the period 1948-1964 show a maximum 1-hour total of 0.75 inch, 3-hour total of 1.05 inches, 6-hour total of 1.65 inches, and the maximum 12-hour total was 2.55 inches. Measurable snowfall occurs in five out of six winters with several storms providing maximum depths of only 1 to 2 inches. Most snow cover remains only a few days, with the exception of a record depth of 27 inches which occurred January 1969 and remained for 13 days (U.S. Department of Commerce, 1973).

Precipitation records for Portland, Oregon (located 180 miles north of Roseburg) show a similar distribution pattern. The Portland area receives 44 percent of its annual moisture in winter, 21 percent in spring, 8 percent in summer, and 26 percent in fall. The Portland precipitation records were used in the synthesis of flood peaks because of similar patterns and the availability of precipitation records from previous studies (Laenen, 1980, 1983). Refer to the section of this report pertaining to flood-peak synthesis for further comparison of the the precipitation records.

# DATA ACQUISITION

Data aquisition was divided into two phases. The first phase required the establishment of a network for collecting rainfall-runoff data. The second phase required the collection or measurement of independent basin characteristics for use in multiple-regression analysis. Data collection began January 1982 and ended May 1984. Locations of the rainfall and streamflow collection sites are shown in figure 1. Table 1 gives station numbers, location, and type of gage.

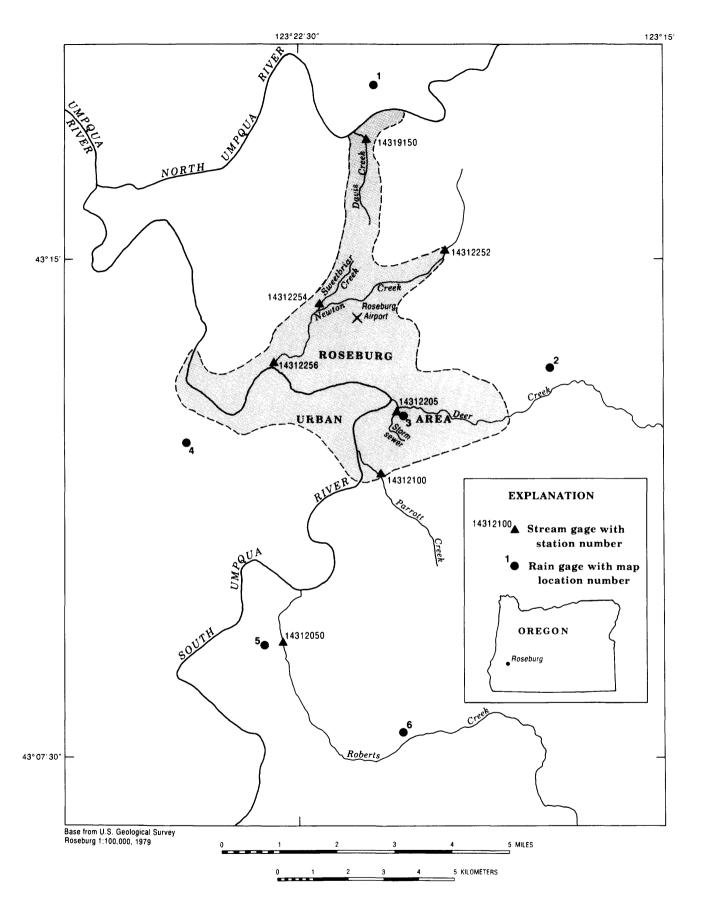


Figure 1. Location of data-collection sites in the Roseburg area, Oregon.

Table 1.-- Gage identification and location

Gage identifier	Site, type of gage, and location
	Streamflow gages
14312050	Roberts Creek, continuous discharge gage, on left bank upstream side of bridge at Green Siding Road
14312100	Parrott Creek, crest-stage gage, on left bank upstream end of culvert at Starmer Street
14312205	Court Street storm sewer, continuous discharge gage, at outfall of storm sewer into Deer Creek
14312252	Newton Creek, continuous discharge gage, on right bank upstream side of bridge at Sterling Drive
14312254	Sweetbriar Creek, crest-stage gage, on left bank upstream end of culvert at Stewart Parkway
14312256	Newton Creek, continuous discharge gage, on left bank upstream side of bridge at Jefferson Street
14319150	Davis Creek, crest-stage gage, on right bank upstream end of culvert at Page Road
	Rainfall gages
1	Lat 43°17' long 123°21'; Douglas County Park Headquarters at Winchester
2	Lat 43°13' long 123°17'; near intersection of Diamond Lake Blvd. and Sunshine Road
3	Lat 43°12' long 123°20'; Justice Building (tipping bucket rain gage)
4	Lat 43°12' long 123°24'; west Roseburg, near intersection of Old Melrose Road and Meadow Lark Lane
5	Lat 43°09' long 123°23'; Fire District No. 2, Substation No. 2, Green District
6	Lat 43°08' long 123°20'; Near intersection of Roberts Cree Road and Glengary Road

# Data-collection Network

Six rain gages (five collector/float rain gages and one tipping-bucket rain gage) were operated in conjunction with this study. The collector/float rain gage consisted of an analog-to-digital recorder (ADR) mounted on top of a 3-inch (inside diameter) collector pipe. Rain was funneled into the collector pipe and a float inside the pipe transferred the water-surface elevation by wire, float wheel, and counter weight to the ADR recorder. The ADR recorded the water-surface elevation at 5-minute intervals on a 16-channel paper tape. The collector pipe held approximately 4 inches of rainfall before an automatic syphon action took place and emptied the pipe. Gages were visited monthly by personnel from the Douglas County Water Resources Survey. During each visit, the gages were checked for proper operation, collector pipes were drained, and the paper tape records were removed for processing.

The streamflow (runoff) network consisted of four continuous-recording gaging stations and three crest-stage gages. The stilling well for each continuous-recording gage consisted of a 4-inch (inside diameter) pipe with inlet holes in the bottom cap. A wire attached to a float and counterweight transferred the water-surface elevation to the ADR recorder mounted on the top of the stilling well. Stream levels were recorded at 5-minute intervals. Streamflow discharge measurements were made when possible to define a stage-discharge relation for each site. In addition to the continuous recording gages, three crest-stage gages were operated to supplement peak-stage information. The crest-stage gages only recorded the maximum stage between monthly inspection visits.

The Parrott Creek crest-stage gage was established prior to this study and used as a check against long-term synthetic simulation methods. Data collection at this site began November 1951.

# Basin Characteristics

The drainage basin characteristics that were evaluated in the regression-analysis phase of this study are given in table 2. Characteristics are defined below (acronyms are shown in parentheses):

Drainage Area (DA).--The area in square miles, measured in a horizontal plane, that is enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the stream. Basin boundaries were delineated by outlining drainage divides on orthophoto-contour maps (scale 1 inch equals 100 feet)--where available--or U.S. Geological Survey 15-minute topographic series maps (scale 1:62,500), and then adjusting the natural areas where necessary to agree with the current storm-sewer grid.

Mapped Impervious Area (MIA).--Percentage of the drainage basin that is covered by impervious surfaces such as roofs, driveways, streets, and so forth. For the Roseburg basins, MIA was determined by multiplying the number of buildings (counted on photographs of 1 inch equals 100 feet scale) by an average amount of impervious area per building as determined for sample areas. Only a part of the MIA may be effective for producing streamflow (see Effective Impervious Area).

Table 2...<u>Drainage basin characteristics</u>
[mi<sup>2</sup> = square miles; ft/mi = feet per mile; \* represents contributing drainage area..total drainage area = 0.06 mi<sup>2</sup>]

Station	Station	Drain- age <sub>2</sub>	Imperi area perce	, in	Storage	Average annual precipi- tation	6-hour rain- fall		Basin slope	Channel slope	Channel Length	Sewered area	soil	ologi s gro cent	up)	sin)	Soil infiltration
number	name	٠.۷.	EIA	MIA	(percent)	(inches)	(inches)	shape	(ft/mi)	(ft/mi)	(mile)	(percent)	A	В	С	D	(inch/hour)
14312050	Roberts Creek	21.4	3	1.9	0.1	38	2.5	2.26	1,190	97.9	9.26	0		21	34	45	0.09
14312100	Parrott Creek	2.42	5	1.6	0	37	2.5	1.82	1,690	383	2.23	0			25	75	.04
14312205	Storm sewer outfall	.03*	50	63.4	0	34	2.5	5.04	858	453	0.55	56.5			15	85	••
14312252	Newton Creek at Sterling Drive	3.05	2	2.4	0	36	2.5	2.05	1,640	220	3.02	2.5		1	2	97	.03
14312254	Sweetbriar Creek	1.78	5	7.9	0	35	2.7	1.26	550	174	1.84	5.2		22	28	50	.09
14312256	Newton Creek at Jefferson Street Bridge	6.99	10	7.5	.2	36	2.7	3.03	810	96.2	5.54	8.4		8	10	82	.05
14319150	Davis Creek	2.12	2	7.0	0	36	2.8	1.21	1,240	287	2.60	0		1	45	54	.06

Effective Impervious Area (EIA).--The amount of impervious area that is effective in producing streamflow expressed as a percentage of the total drainage area. The variable is not measurable on maps; its value is obtained either by optimizing the variable in a rainfall-runoff model or from an equation developed by Laenen (1980) which relates EIA to MIA. EIA was determined by optimization for the Roseburg basins. For low amounts of impervious area EIA may be greater than MIA. One possible explanation for this is that a few streets may become efficient conduits even though they cover a small part of the basin.

EIA is an index of urbanization. This parameter is related to the total impervious cover of a basin and the impervious-cover linkage to the main channel (or trunk sewer). Because EIA cannot be defined on maps or in the field, it was estimated by using an optimal fitting technique with the digital rainfall-runoff model. Although this technique lumps many soil and topographic characteristics together (including the impervious area), it still yields a reasonable estimate of the effectiveness of the hydraulic linkage in the system. These values are listed in table 2.

EIA was determined by an optimal fitting technique using the rainfall-runoff model. All parameters, with the exception of impervious area, were held constant. Model runs were made for various values of impervious area and a plot was made of the resulting standard error compared with the impervious area, as a percentage of the basin. The low point (the best standard error) of this curve defined the optimal impervious area. This computer-modeled optimal impervious value is, for all practical purposes, the effective impervious area (Laenen, 1980).

Laenen (1983) used EIA as a significant parameter in the estimating equations for the Willamette Valley in order to evaluate the changes in flood statistics as the degree of urbanization is changed. On the basis of Willamette Valley data, Laenen concluded that a relation exists

between mapped impervious area (MIA) and effective impervious area (EIA). The following equation, which has a SEE of 27 percent, defines that relation:

$$EIA = 3.6 + 0.43(MIA)$$

where.

EIA = effective impervious area, in percent of basin area; and MIA = mapped impervious area, in percent of basin area (for the range 2 to 50 percent).

Storage (ST).--The index of surface storage in the basin where water can be stored during a storm. Surface area of depressions is divided by the drainage area and is expressed as a percentage of the total drainage basin area. The storage for a basin with 1.2 percent of the basin being available for storage would be expressed as 1.2.

Average Annual Precipitation (AAP).--The average annual precipitation, in inches, for the drainage basin. This value was estimated using a rainfall map (scale 1:12,500) prepared by Douglas County Water Resources Survey from available precipitation records compiled through 1977.

Rainfall (RI50).--The 50-year (exceedance probability of 2 percent) 6-hour precipitation, in inches, for the drainage area, determined from 1:2,000,000 scale rainfall maps (Miller and others, 1973). In this report, the variable is commonly referred to as intensity, although it is actually a rainfall total for a 6-hour period.

Basin Shape (BSP).--The ratio of the length to the average basin width calculated by the formula:

$$BSP = Lc^2/DA$$

where,

Lc = the straight-line distance in miles from the basin outlet to the point on the basin divide that was used to determine the main channel length, and

DA = the drainage area of the basin, in square miles.

Basin Slope (BSL).--The average slope for the basin, in feet per mile, computed from U.S. Geological Survey 15-minute topographic maps (scale 1:62,500), using the formula described by Wisler and Brater (1949):

$$BSL = (C*L)/DA$$

where.

C = contour interval of the map, in feet;

L = total length of the contour lines within the drainage basin, in miles; and

DA = drainage area, in square miles.

Channel Length (CL).--The length of the main channel, in miles, from the gaging station or other point of interest to the basin divide. The upstream end of the system is determined by extending the main channel from the end of the mapped representation of the stream (blue line) to the basin divide.

Channel Slope (CSL).--An index of the slope of the main channel, in feet per mile, computed from the difference in streambed elevation at points 10 percent and 85 percent of the distance from the gaging station or other point of interest to the basin divide (see channel length) divided by the distance, in miles, between the two points. The formula can be expressed as:

$$CSL = (elev_{85} - elev_{10}) / (0.75*CL)$$

where,

elev<sub>85</sub> = streambed elevation at a point 85 percent of channel length upstream of the gaged site, in feet;

elev<sub>10</sub> = streambed elevation at a point 10 percent of channel length upstream of the gaged site, in feet; and

CL = channel length, in miles.

Sewered Area (SA).--The area, in percentage of total drainage, that is serviced by storm sewers. For the Roseburg study, SA was taken from drainage maps supplied by the city of Roseburg. In computing the sewered area, it was assumed that all areas within 1 city block from the outermost catch basins would drain to the catchment basins.

Soil Infiltration Rate (INFL).--Average rate at which water infiltrates into the soil, in inches per hour. It is determined by averaging ranges for each soil group defined by the U.S. Soil Conservation Service and then weighting them by percentage of total basin covered. The percentage of the basin covered by soil-group types A through D was determined from recent unpublished soil maps (scale 4 inches = 1 mile) and soil surveys available from the Soil Conservation Office, Roseburg, Oregon. The range of infiltration rates, in inches per hour, is shown in the following definitions:

- A. (Low runoff potential). Soils having a high infiltration rate, even when thoroughly wetted, and consisting chiefly of deep, well-drained to excessively drained sand or gravel [0.45 0.30 inches/hour].
- B. Soils having a moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse texture [0.30 0.15 inches/hour].
- C. Soils having a slow infiltration rate when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture [0.15 0.05 inches/hour].

D. (High runoff potential). Soils having a very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent highwater table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material [<0.05 inches/hour].

# ANALYTICAL TECHNIQUE

A rainfall-runoff model was calibrated for each basin from observed rainfall, evaporation, and discharge data collected during the period January 1982 to May 1984. The rainfall-runoff model was used to generate a set of annual flood peaks for each study basin from 71 years of historical data.

# Digital Modeling

The U.S. Geological Survey rural rainfall-runoff model (A634) developed by Dawdy, Lichty, and Bergman (1972) was calibrated and used for each study basin to simulate storm runoff from historic storm rainfall. Data collected for the period January 1982 to May 1984 were entered into the model as daily rainfall and evaporation (to define antecedent moisture conditions) and as 5-minute rainfall totals and corresponding streamflow discharges for individual storm. During the model-calibration phase for each basin, model variables were optimized to yield the best relation between statistical modeled and observed storm runoff.

For this project, the rainfall-runoff model was used to optimize (estimate) effective impervious area (EIA), and the four interacting soil parameters--PSP, KSAT, RGF, and BMSM for each basin. An explanation of these terms and the calibrated-model variable values for the Roseburg sites are shown in tables 3 and 4. Refer to Dempster (1974) or Laenen (1980) for values of other variables, for detailed comments on use of the model, and for application of the model.

#### Model Calibration

Personnel from the U.S. Geological Survey and Douglas County selected sites where it appeared possible to develop valid rainfall-runoff and stage-discharge relations. This section is intended to help describe the seven basins selected for this project. Basin characteristics and calibrated model parameters are listed in tables 2 and 4, respectively. The storms used to calibrate each basin are listed in the appendix of this report.

#### Roberts Creek

The Roberts Creek basin, with a drainage area of 21.4 square miles, was the largest of the seven basins gaged. The basin is located 6 miles south of downtown Roseburg. The gage was located approximately 1 mile upstream from the mouth. Land use in the upper part of the basin is agricultural (grazing lands), whereas residential development exists on the level valley floor in the lower portion of the basin. The main channel meanders through a broad flood plain in the lower part of the basin.

Table 3.--<u>Identification and definition of parameters used in the</u>
digital model (modified from Dempster, 1974)

Component	Parameter identifier	Units	Definition
	EVC		Pan Coefficient that converts pan evaporation to potential evapotranspiration.
Antecedent- moisture accounting	RR		Coefficient that proportions daily rainfall into infiltration and surface runoff.
	BMSM	Inches	Maximum effective soil- moisture storage volume at field capacity.
	DRN	Inches per hour	Constant coefficient that controls drainage rate of infiltrated soil moisture.
	PSP	Inches	Capillary potential, or soil suction, at wetted front for field-capacity conditions.
Infiltration	RGF		Ratio that varies PSP over the soil-moisture range from wilting point to field capacity.
	KSAT	Inches per hour	Minimum saturated value of hydraulic conductivity to determine infiltration rates
Routing	TC	Minutes	Time characteristic for translation of rainfall excess by distance-area histograms.
	KSW	Hours	Time characteristics for linear reservoir routing.

An extreme storm occurred just prior to installation of the recording equipment. During a 2-day period, approximately 7 inches of rain fell over the basin, resulting in peak discharge of  $3,710~\rm{ft^3/s}$  (cubic feet per second) on December 6, 1981. This peak was included in the model calibration using 15-minute rainfall data obtained from the National Weather Service.

Hydrographs of one representative observed storm and the corresponding model-synthesized storm for the period are shown in figure 2. A statistical comparison of the peak discharges from the 14 storms used to calibrate the basin resulted in a coefficient of determination (R<sup>2</sup>) of 0.97. Data observed from this basin indicate rapid runoff from storms. For this basin, the model timing coefficient (Tc), a routing parameter, was a reasonable 235 minutes, but the storage coefficient (KSW) was only 2 hours, very short for such a large basin. Lag time, the time elapsed from the beginning (or center of mass) of rainfall to the peak of runoff, was calculated to be 4.9 hours and is an extremely short time for a basin of this size, especially when considering this is primarily a rural basin. A similar-sized basin in the Portland study,

Table 4.--Calibrated basin parameters
[See table 3 for definition of specific basin parameters and units used]

			nteceder	nt-						Mo	del statistics
Station number	RR	EVC	BMSM	DRN	PSP	nfiltrat RGF	ion KSAT	TC	ting KSW	Sample size	
14312050	0.75	0.76	25.4	1.00	3.18	4.00	0.022	235	2.00	14	0.97
14312100	.75	.76	28.0	1.00	.70	8.87	.040	130	2.50	11	. 96
14312205	.75	.76	43.5	1.00	.73	23.5	.031	10	.60	11	. 62
14312252	.75	. 76	28.1	1.00	.70	8.87	.037	125	2.70	12	. 96
14312254	.75	.76	28.0	1.00	.70	8.87	.040	125	3.50	11	. 86
14312256	.75	.76	13.4	1.00	2.07	24.1	.036	177	4.00	11	. 87
14319150	.75	.76	28.0	1.00	.70	8.87	.040	120	1.50	9	. 86

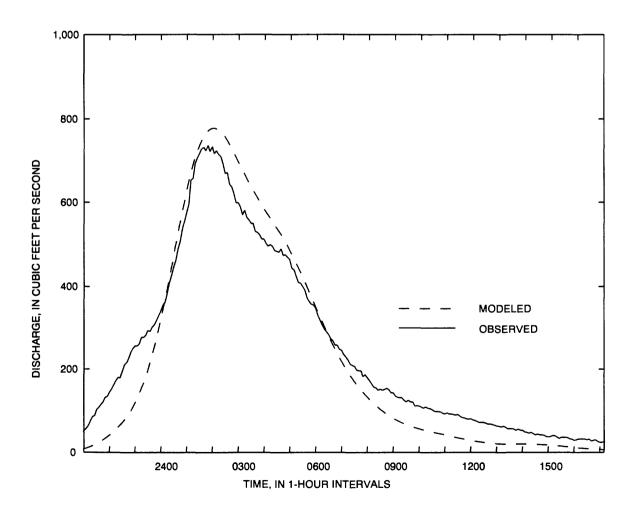


Figure 2. Observed and modeled hydrographs for March 29-30, 1983 at Roberts Creek gage.

Johnson Creek, produced a lag time of 25 hours. With the exception of time, all other parameters for this basin were within the expected range. The unusual response of this basin could not be affixed to any apparent cause. Refer to the report by Carrigan (1973) for a discussion of the routing parameters, Tc and Tp, and the storage coefficient KSW.

#### Parrott Creek

Parrott Creek was the only basin in the study area where previous peak flow data had been collected. Refer to the "Verification of Methods" section of this report for a discussion of the previously collected data and the data used for verification.

The Parrott Creek basin is located 2 miles south of downtown Roseburg. The upper basin is generally undeveloped agricultural land. The gage was located approximately where the stream entered the southern residential area of Roseburg. No unusual circumstances that would affect the model calibration were noted, and all parameters were within the expected range.

# Court Street Storm Sewer

This basin, located in the downtown area of Roseburg, was the most urbanized of the seven basins in this study. Most of the basin (56.5 percent) was drained by a storm sewer system. The gage was located at the outfall of the system into Deer Creek. This gage was installed the second year of the project, resulting in the availability of only 2 years of storm data for the analysis.

Basin runoff from storms of long duration could not be recorded at this gage because the outfall pipe from the storm sewer system was located below normal high water levels of Deer Creek. The stage-discharge relation for this site was valid as long as the water surface of Deer Creek was below the outfall pipe. Several of the larger storm events could not be used for model calibration because of the backwater conditions; however, short duration high intensity storms provided adequate events for calibration.

Flood-frequency curves based on the data generated by the model for this basin showed less discharge for a given recurrence interval than those obtained by estimating equations. This difference can be partially explained by the influence of the storage variable used in two of the three estimating equations. No channel storage (a volume of water in the channel or over the flood plain of a drainage basin) could be detected for this small basin (0.06 square miles); however, detention storage can occur in storm-drain sewers when undersized pipes are present. A very small (0.5 percent) increase in the storage variable in the estimating equations would bring the discharge estimates in line with those for nearby basins.

It also was noted in model calibrations that peak discharge was being overestimated by a considerable amount. The city of Roseburg Engineer's Office said that it has been a practice in this part of the city to connect the roof drains of commercial buildings to the sanitary sewer, thus diverting considerable runoff from the storm-water sewer system. This practice has now been discontinued, and the city has

instituted a program to re-connect roof drains to the storm-water sewer. To account for this circumstance in the model, the drainage area for this basin was re-estimated to eliminate the drainage area accounted for by commercial buildings.

# Newton Creek at Sterling Drive

This gage, located at the Sterling Drive box culvert, was the farthest upstream of three streamflow gages in the Newton Creek basin. The drainage area of 3.05 square miles represents the upper 46 percent of the basin. The basin is approximately 3 miles north of downtown Roseburg. Land use in this basin is primarily agricultural/timber lands with residential development only in the vicinity of the gage.

The gage was located on the upstream wingwall of a non-standard box culvert (8.5 feet wide by 9.3 feet in height). The stage-discharge relation was developed by a series of current-meter measurements. As with Roberts Creek, no recording equipment was installed prior to the December 6, 1981 flood peak. An indirect measurement, based on the high-water marks of the peak, indicated a peak of 495 ft<sup>3</sup>/s. This peak was included in the calibration using 15-minute rainfall data obtained from the National Weather Service for the Roseburg KQEN weather station. The calibrated basin variables were within the expected range for this site.

#### Sweetbriar Creek

The Sweetbriar Creek drainage is located 3 miles northwest of downtown Roseburg and is tributary to Newton Creek. Sweetbriar Creek enters Newton Creek approximately halfway between the gages at Sterling Drive and Jefferson Street bridge. Land use in the basin is primarily residential, but a hospital complex was being developed near the gage site at the time of the study. During the final year of the project, a shopping center was built downstream of the gage, resulting in a change in the stage-discharge relation for this site. No unusual conditions were noted during the calibration phase of this study.

# Newton Creek at Jefferson Street Bridge

This gage, located 0.5 mile upstream from the mouth and 2 miles west of downtown Roseburg, measured runoff from most of the Newton Creek basin. The basin is composed mainly of residential developments, most of which are served by storm sewers, a large shopping center complex in mid-basin, and a small wildlife refuge (park). It was noted that while attempting to reconstruct the December 6, 1981 peak at this site, a survey of the high-water marks indicated that the gage site was affected by backwater from the South Umpqua River. Several other peaks during the study period were not used for calibration due to unknown effects of backwater; however, an adequate number of peaks were available for calibration. Currentmeter measurements provided the basis for the stage-discharge relation at this site.

#### Davis Creek

The Davis Creek basin lies north of the Newton Creek basin, approximately 4 miles north of Roseburg and at the community of Winchester. Davis Creek is tributary to the North Umpqua River. Development in the basin is limited to a small area of residential development with most of the basin consisting of agricultural/timber lands. The basin was monitored using a crest-stage gage in the approach section of a 8 foot by 6 foot box culvert under Page Road. No unusual conditions were noted during the calibration of this basin.

# Flood-peak Synthesis

Flood-peak synthesis is the process whereby flood discharges are generated from long-term daily rainfall, daily evaporation, and unit rainfall by a calibrated rainfall-runoff model. The model generates flood hydrographs for each rainfall-runoff site for each storm entered. Annual peak discharges are selected from the synthesized data.

The evaporation data used for the synthesis were collected at the North Willamette Valley Experimental Station near Canby, Oregon, 165 miles north of Roseburg. The period of record was extended by Laenen (1980) from the initial 10 years (1964 to 1973) to 71 years (1903 to 1973) by harmonic analysis using existing data patterns. Comparisons of available records made by Laenen (1983) indicate that daily evaporation does not vary greatly through the area.

Rainfall data collected at the National Weather Service recording rain gage at the Custom House in Portland, Oregon, 180 miles north of Roseburg, were used for the long-term analysis. Previous work by Laenen (1980 and 1983) indicated identical precipitation distributions using Cramer-Von Mises statistical tests (Conover, 1972) for Portland-Vancouver, Salem, and Roseburg. Because the Portland-Vancouver storm data were readily available, these data were used to simulate a long-term record for the period 1903 to 1973 for the Roseburg basins. The similarities in rainfall intensity duration-frequency curves are shown in figure 3.

# Flood-frequency Analysis

The U.S. Geological Survey rainfall-runoff model was run, for the period 1903 to 1973, using final calibration variables determined for each of the seven streamflow stations. In addition, unit and daily rainfall and daily evaporation values were included in the data set, in order to simulate a series of annual peaks at each of the streamflow stations. A Log-Pearson Type III frequency curve was fitted to each series of flood peaks in accordance with the guidelines contained in U.S. Water Resources Council Bulletin 17B (1981). These synthetic peaks are summarized for selected recurrence intervals in table 5.

The flood-frequency curves computed from the generalized peaks were compared with frequency curves derived from three predictive equations: (1) WOr Rogue-Umpqua equations (Harris and others, 1979);

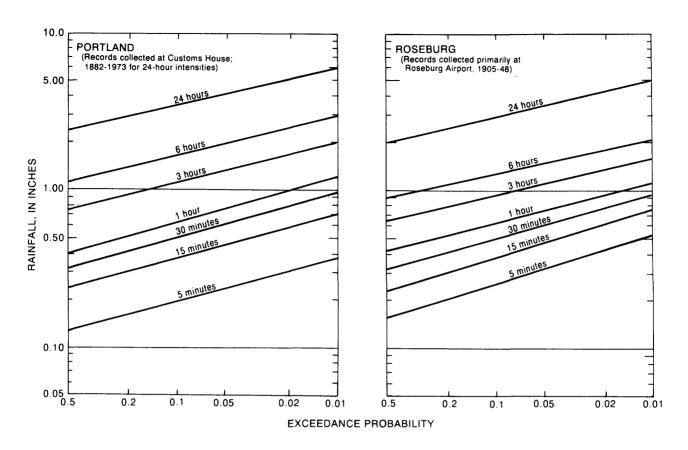


Figure 3. Exceedance probability for rainfall intensities for Portland and Roseburg, Oregon.

Table 5.--Summary of flood-peak discharges for given recurrences from frequency computations based on generated peaks

 $[mi^2 = square miles; 1/represents contributing drainage area--total drainage area = 0.06 <math>mi^2$ ]

Station	Drainage area	Dis	Discharge, in cubic feet per second, for recurrence interval, in years								
number	(mi <sup>2</sup> )	2	5	10	25	50	100				
14312050	21.4	1,420	2,180	2,700	3,370	3,870	4,380				
14312100	2.42	170	250	310	380	440	500				
14312205	1/.03	4.9	6.7	8.1	9.9	11.3	12.8				
14312252	3.05	210	310	390	480	550	610				
14312254	1.78	110	170	200	250	290	330				
14312256	6.99	290	490	620	780	900	1,010				
14319150	2.12	180	270	330	410	460	520				

(2) equations W-1 (Laenen, 1983), and (3) three-parameter estimating equations N-5 (Sauer and others, 1983). The relations for all seven Roseburg stations are shown in figure 4.

The Willamette Valley equations (W-1) estimated the Roseburg flood-peak statistics within +20 percent and -16 percent (within the average standard error of estimate reported for the equations) with two exceptions. These equations underestimated the magnitude of the peaks for Roberts Creek by an average of 44 percent and overestimated the magnitude of the peaks for the Storm Sewer site by 55 percent.

Peak flow values for seven sites were within the average 46 percent standard error defined by Harris's WOr Rogue-Umpqua equations. Values ranged from a -30 percent for the Storm Sewer site to +28 percent at the Sweetbriar site.

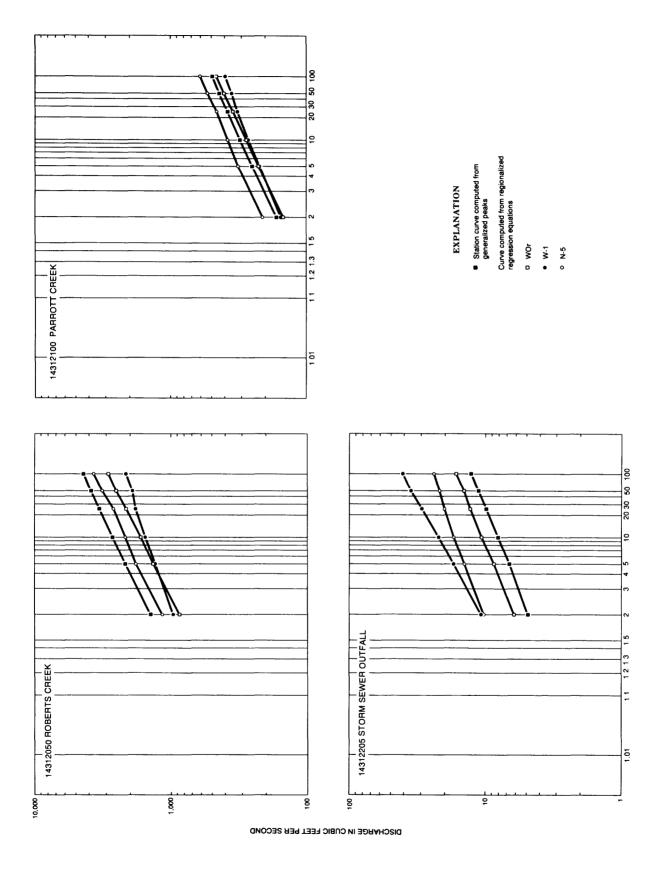
Peak flow values for six of the seven sites were overestimated using Sauer's three-parameter equations. The Roberts Creek statistics were the only set underestimated by these equations. The Roberts Creek values averaged -18 percent, still within the average 43 percent range of error. The flood statistics for the six other sites were overestimated with average values ranging from a +11 percent for the Davis Creek values to +49 percent for the Sweetbriar values. The Sweetbriar flood statistics were the only values to exceed the 43 percent range of error.

An attempt was made to improve the standard error of estimate in Laenen's W-1 equations by combining the basin and climatic characteristics for the seven Roseburg sites with the data available for the 41 sites used in the Willamette Valley. Results of the regression analysis indicated little change in constant and exponent values. The analysis also indicated no improvement in coefficient of correlation and the standard error of estimate increased from an average of 24 percent to 30 percent.

A second regression analysis was made using only data from the seven sites in Roseburg. As in the other regression analysis, drainage area was the most significant variable, followed by average annual precipitation and rain intensity. No improvement was shown as additional variables were added. However, the analysis of such a small dataset (seven samples) is not statistically valid, and therefore the results are not presented in this report.

# Verification of Methods

The Parrott Creek crest-stage gage (14312100) was the only site within the study area for which prior peak-flow data were available. Peak-flow data collection began at this site October 1951 and continued until termination of this project in 1984. The observed record provided a verification of the procedures used in this study. The frequency curve, based on peaks generated by the model from Portland rainfall data, closely replicated the frequency curve that is based on observed data. The frequency curve from the calibrated basin model was within +10 percent of the observed 2-year event and within -12 percent of the observed 100-year event.



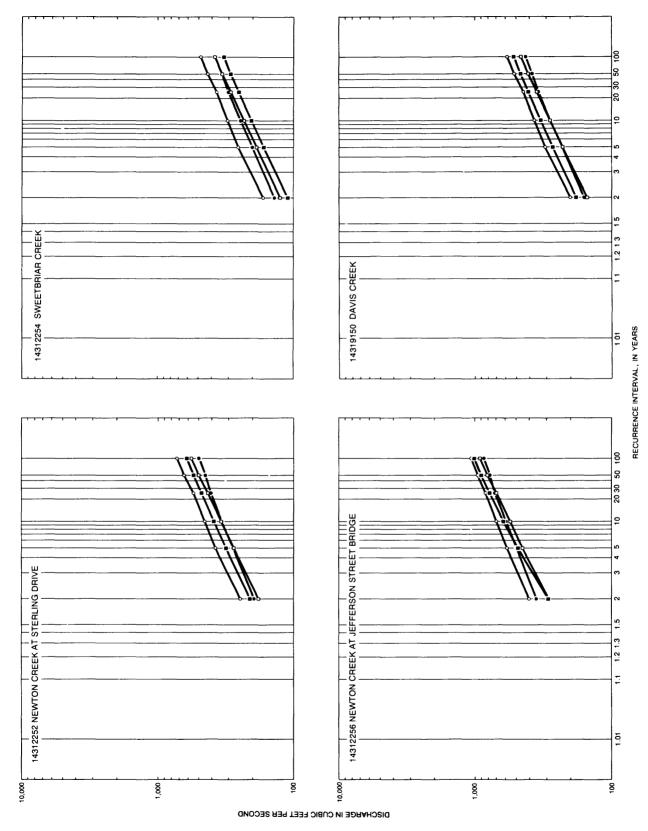


Figure 4. Estimates of flood frequencies by various procedures for seven sites near Roseburg, Oregon.

annual storms contained in the Portland rainfall data produced the annual peaks in the Roseburg area. This was determined by comparing dates of the annual peaks between the Parrott Creek gage and the Johnson Creek gage (14211500) in Portland. The larger magnitude storms generally covered the area from Roseburg to Portland, the lesser magnitude storms tended to be localized. The length of record was extended for the peak analysis to 50 years, based on the historic December 1964 storm which produced peaks at both sites. Peaks from this storm ranged from a 50-year event upwards to a 100-year event in this area.

# Regression Analysis

There is need for information on magnitude and frequency of floods for sites without record of peak flows. Equations relating flood flows at gaged sites to easily measured basin and climatic characteristics provide a means for determining flood flows at ungaged sites (Riggs, 1973). Through multiple regression analysis, equations can be developed to relate the discharge of a given flood frequency (dependent variable) to a series of basin characteristics (independent variables). Measures of accuracy of the relation and the usefulness of each independent variable in the relation can also be defined. From Riggs (1973), the regression equation has the general form:

$$Q(t) = c(A)^{a}(B)^{b}...(N)^{n}$$

where, Q(t) is the peak discharge for a t-year interval; A, B, and N are basin characteristics; and a, b, and n are constants for recurrence interval t. The regression equation and applicable coefficients and exponents developed by Laenen (1983) for use in the Willamette Valley are shown in table 6.

Table 6.--Regression model and applicable coefficients and exponents for use in determining flood-peak discharges for selected recurrence intervals (Laenen, 1983)

Regression model equation:  $Q(T) = a * (DA)^b * (EIA)^c * (ST +0.1)^d$ 

where.

Q = flood-peak discharge for recurrence interval, T, in years;

a = regression coefficient;

DA = drainage area;

ST = storage parameter;

EIA = effective impervious area

R<sup>2</sup> = pertains to the log-transformed regression, but SEE is an average of the transformed back-from log to normal

b, c, d = regression exponents

Recurrence	Exceedance		Regr	ession ex	ponents	Coefficient of determination,	error of
interval, T, in years	probability, in percent	· · · · · · · · · · · · · · · · · · ·	b	c	đ	R <sup>2</sup>	estimate (SEE), in percent
2	0.5	26.8	0.90	0.34	-0.20	0.95	24
5	.2	37.0	. 88	.36	21	. 95	23
10	.1	46.3	. 87	. 37	22	. 95	23
25	.04	50.8	. 86	. 40	22	. 95	24
50	.02	56.1	. 84	. 41	22	. 95	24
100	.01	60.4	. 84	. 42	23	.94	25

#### ILLUSTRATIVE PROBLEM

The regression equations presented in this report can be used to compute estimated flood-peak discharges for selected exceedance probabilities (recurrence intervals) at ungaged urban sites in western Oregon.

For example, to determine the flood-peak discharge for an exceedance probability of 0.04 (25-year flood event) for an urban watershed in the Roseburg area, the general form of the equation from table 6 is:

$$Q(25) = 50.8 * (DA^{0.86}) * (EIA^{0.40}) * ((ST + 0.1)^{-0.22})$$

The drainage area (DA) was planimetered from the best available topographic map and determined to be 1.26 square miles (806 acres).

In this particular watershed, it is known that a total area of 5 acres will be inundated during periods of storm-water runoff due to the water being detained by undersized road culverts. The storage index (ST) is computed as:

Percent Storage (ST) = 5 acres / 806 acres \* 100 = 0.6 percent

Effective Impervious Area (EIA) will be estimated using its relation to Mapped Impervious Area (MIA). In this watershed, a total of 60 acres was determined impervious to the infiltration of rain. This represents a total of impervious areas such as paved roads, paved parking lots, roofs, and so forth. The MIA index is computed as follows:

Percent MIA = 60 acres / 806 acres \* 100 = 7 percent

EIA can then be estimated as follows:

$$EIA = 3.6 + (0.43 * MIA) = 3.6 + (0.43 * 7) = 6.6$$
 percent

Substituting the estimated values into the equation:

$$Q(25) = 50.8 * (1.26^{0.86}) * (6.6^{0.40}) * ((0.6 + .1)^{-0.22}) = 50.8 * 1.22 * 2.13 * 1.08 = 143 \text{ ft}^3/\text{s}$$

#### SUMMARY AND CONCLUSIONS

A network of four continuous-recording streamflow gages, three crest-stage gages, and six precipitation gages was established and operated for a 3-year period (1982 to 1984). The USGS rainfall-runoff model was calibrated for each site where runoff was measured. Long-term flood-peak statistics were generated for each site by using the calibrated basin model, along with long-term rainfall and evaporation data from the Portland area.

The Willamette Valley equations (W-1) estimated the Roseburg flood-peak statistics within +20 percent and -16 percent (within the average standard error of estimate of 24 percent reported for the equations) with two exceptions (Storm Sewer +55 percent and Roberts Creek -44 percent). No improvement was shown when a regression analysis was made using a combined data set of Roseburg and Salem-Portland; the average standard error of estimate increased from 24 percent to 30 percent.

#### ADDITIONAL STUDIES

Confidence in using the W-1 equations for estimating flood-peak discharges for Roseburg urban area could be increased with additional study. Several areas of data collection and analysis could be investigated:

- (1) More watersheds in the Roseburg area could be measured and analyzed. Results from the regression analysis using only the seven sites in Roseburg indicated that a different rainfall-runoff relation may exist for this area. Additional data collection and modeling in this area could answer this question.
- (2) Watersheds in other urban areas of western Oregon could be investigated. At present rainfall-runoff data are not available in areas of similar climate, such as Eugene, Sutherlin, or Grants Pass. In addition, a study could be made for coastal urban watersheds, such as Astoria, Tillamook, Newport, or Coos Bay-North Bend.
- (3) There is also a need for more information about highly urbanized basins in other areas outside the Willamette Valley. For this study, only one basin in the seven contained an urban area. The only highly urbanized basin (Storm Sewer) had an undeterminable drainage area, which created a large uncertainty.

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APPENDIX
Station: 14312050 Roberts Creek

Storm number	Date of peak	Time of peak	Storm rainfall	Observed peak discharge	Base flow	peak discharge minus base flow	Simulated peak discharge <sup>1</sup>
1	22/05/81		5.66	3710	150	3560	3420
2	1/23/82	0510	. 24	276	110	166	128
3	2/14/82	0640	.40	315	100	215	257
4	12/15/82	0340	1.22	1060	150	910	703
5	12/16/82	1900	.89	819	270	549	752
6	12/17/82	2155	1.03	843	260	583	856
7	1/26/83	1455	. 85	606	165	441	374
8	2/17/83	2435	2.08	2200	200	2000	1560
9	2/20/83	2230	.61	244	50	194	136
10	3/13/83	0605	1.03	289	90	199	247
11	3/30/83	0205	.92	882	145	737	778
12	12/06/83	2235	2.05	639	90	549	464
13	12/30/83	0240	. 47	919	120	799	653
14	2/13/84	1020	1.42	1200	110	1090	1100

<sup>1</sup> Does not include base flow.

Station: 14312205 Storm Sewer Outfall

Storm number	Date of peak	Time of peak	Storm rainfall	Observed peak discharge	Base flow	Observed peak discharge minus base flow	Simulated peak discharge <sup>1</sup>
1	1/02/83	0905	1.04	2.5	0.07	2.4	1.6
2	2/25/83	2345	. 70	3.3	.10	3.2	2.6
3	3/10/83	0025	.73	4.8	.10	4.7	3.7
4	3/12/83	0505	.51	2.8	.10	2.7	1.6
5	3/29/83	2230	2.01	3.8	.12	3.7	5.0
6	11/13/83	0600	2.82	4.7	.06	4.6	6.8
7	12/06/83	1315	1.81	2.6	.10	2.5	2.1
8	12/28/83	2055	. 26	1.4	.10	1.3	1.0
9	12/30/83	0005	.93	4.3	.12	4.2	3.6
10	2/24/84	1620	1.80	3.1	.10	3.0	4.6
11	3/14/84	0055	1.17	2.8	.07	2.7	2.1
12	4/07/84	2230	1.39	4.2	.08	4.1	6.6

<sup>&</sup>lt;sup>2</sup> Prior to installation of recording equipment. Discharge determined by indirect measurement of flow. Storm rainfall data obtained from National Weather Service.

APPENDIX--Continued

Station: 14312252 Newton Creek at Sterling Drive

Storm number	Date of peak	Time of peak	Storm rainfall	Observed peak discharge	Base flow	Observed peak discharge minus base flow	Modeled peak discharge <sup>1</sup>
1	<sup>2</sup> 2/05/81		5.66	415		495	468
2	2/14/82	0520	1.71	59	10	49	51
3	12/16/82	0520	1.16	120	17	103	71
4	12/16/82	1920	1.16	101	32	69	65
5	12/17/82	2010	. 77	100	20	80	75
6	2/18/83	0015	3.07	440	27	413	393
7	3/10/83	0130	. 68	114	13	101	<b>8</b> 5
8	3/29/83	2320	1.45	213	20	193	<b>1</b> 75
9	11/24/83	0835	. 70	96	20	76	53
10	12/06/83	1540	1.89	120	22	98	68
11	12/30/83	0105	.89	109	15	94	137
12	2/13/84	0325	3.41	206	15	191	253

<sup>&</sup>lt;sup>1</sup> Does not include base flow.

Station: 14312256 Newton Creek at Jefferson Street Bridge

Storm number	Date of peak	Time of peak	Storm rainfall	Observed peak discharge	Base flow	Observed peak discharge minus base flow	Modeled peak discharge <sup>1</sup>
1	2/13/82	2205	1.33	133	30	103	90
2	2/14/82	0555	.45	131	50	81	67
3	12/16/82	0350	1.61	223	40	<b>19</b> 5	247
4	12/16/82	1805	1.69	274	50	224	217
5	2/20/83	2245	1.07	88	35	53	38
6	3/10/83	0225	.99	188	20	168	203
7	3/30/83	0015	2.08	269	25	294	409
8	11/24/83	0905	.70	176	40	136	71
9	11/25/83	0755	.37	109	40	69	27
10	12/30/83	0205	.74	185	30	155	96
11	2/24/84	1905	1.18	223	40	183	150

<sup>1</sup> Does not include base flow.

Prior to installation of recording equipment, time unknown, discharge based on observer's notes, high-water marks, and indirect computation of flow. Rainfall data obtained from National Weather Service.

APPENDIX--Continued

Station: 14312100 Parrott Creek (crest-stage gage)

Storm number	Estimated date of peak	Storm rainfall	Observed peak discharge	Base flow	Modeled peak discharge
1	12/05/81	5.66	277	0	377
2	2/13/82	1.71	48	0	40
3	12/15/82	1.16	37	0	56
4	12/16/82	1.16	70	0	49
5	12/17/82	.77	81	0	57
6	2/17/83	3.07	328	0	319
7	3/09/83	. 68	50	0	69
8	3/29/83	1.45	127	0	141
9	11/24/83	. 70	50	0	45
10	12/06/83	1.89	60	0	53
11	12/29/83	. 89	105	0	112
12	2/12/84	2.78	120	0	134

Station: 14312254 Sweetbriar Creek (crest-stage gage)

Storm number	Estimated date of peak	Storm rainfall	Observed peak discharge	Base flow	Modeled peak discharge
1	2/13/82	1.71	38	0	25
2	12/15/82	1.16	92	0	37
3	12/16/82	1.16	65	0	34
4	12/17/82	.77	56	0	40
5	2/17/83	3.07	215	0	218
6	3/09/83	. 68	88	0	46
7	3/29/83	1.45	140	0	96
8	11/24/83	.70	45	0	29
9	12/06/83	1.89	56	0	38
10	12/29/83	. 89	56	0	74
11	2/12/84	3.41	138	0	140

APPENDIX--Continued

Station: 14319150 Davis Creek (crest-stage gage)

Storm number	Estimated date of peak	Storm rainfall	Observed peak discharge	Base flow	Modeled peak discharge
1	12/15/82	1.16	103	0	51
2	12/16/82	1.93	67	0	53
3	2/17/83	3.07	342	0	320
4	3/09/83	. 68	85	0	67
5	3/29/83	1.45	133	0	132
6	11/24/83	. 70	60	0	51
7	12/06/83	1.89	67	0	53
8	12/29/83	. 89	60	0	128
9	2/12/84	3.41	172	0	210